Notes on "Closing Summary" for the Alignment Workshop

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The afternoon portion of the October 4-5 workshop was the final "wrap up" session. The closing summary was presented after summaries on AP, Mechanical and Magnetic Measurement requirements for alignment. One of the main goals of the workshop was to create an "alignment table" analogous to the magnet field error tables used for inner triplet corrector workshop. The table has been updated since the workshop. This latest table can be located on the alignment workshop web site.

Important points from closing summary:

General comments

This workshop comes rather early in the alignment progress in the inner triplet. It was acknowledged from the beginning that this workshop would not solve all of the alignment issues. Rather the workshop goal was to consider all of the facets of alignment, from AP goal, to magnet construction, magnet measurement, and tunnel installation and survey. The workshop was well represented by parties interested in all phases of these alignment processes.

One the general themes of the workshop was the need to balance the needs of the inner triplet alignment with the financial and man power realities of the LHC. From the various AP presentations, it is clear that good inner triplet alignment is important to the operation of the machine. It is a complicated problem with magnetic elements that are significantly coupled. Still there is a real pressure to keep the alignment program cost effective. Thus we should build only what is really needed. Whenever possible, we should design into the system the possibility to upgrade the system at a future date, as necessary.

Alignment table

See the web site for a detailed description of the table layout. To summarize, the table compares the AP goals, the mechanical construction tolerances and measurement uncertainties during each phase of the inner triplet installations. The program should be successful if the AP, mechanical and measurement values are in the same range. It was agreed by all that the table presented at the beginning of the workshop needs to be embellished, and numbers have to be assigned to each cell in the table. Effects of alignment due to vacuum and thermal changes from RT to operation have not been fully addressed. The alignment situation for Q1, Q2ab and Q3 are different so there should be

separate entries for each. As J.P. Quesnel pointed out, the use of RMS and maximum tolerances need to be spelled out clearly.

In general it looks like the AP goals are matched pretty well to the measurement uncertainties, i.e. one can measure the axis offsets and angles well enough to place the magnetic axes in the AP specified location. The numbers associated with mechanical tolerances are more difficult to estimate, and will be a subject of study in 2000.

AP requirements

Presentations by Jean Pierre Koutchouk, Tanaji Sen and Fulvia Pilat showed that there was a general agreement on the AP goals of the alignment table. Since the beta functions change rapidly in the inner triplet, it was agreed that the effects of local twists in the magnetic axis coordinate system need to be quantified.

Related to the beam pipe requirements, we were reminded that the located of the beam pipe is also important, since its position could effect the physical beam aperture. We are in the process of specifying the beam pipe, thickness and diameter as well as the centering of pipe in the coldmass.

Finally, J. P. Koutchouk pointed out that a straight-line alignment might not be the optimum configuration of the inner triplet, due to the fact that the beams are off axis. If this turned out to be true, we might use this information in placing the magnets in the tunnel.

Survey

J.P. Quesnel gave a talk on the survey and alignment plans in the LHC tunnel. There has been communication between Jean Pierre, Gilbert Trinquart and Tom Nicol about the details of this process. Among the issues to be decided: number, type and location of vacuum vessel fiducials, number and location of jack stands and location of IR survey "line of sights" to horizontal alignment wires.

Measurement issues

Fermilab presented its program to measure the magnetic axes of the quadrupoles and transfer them to the outside fiducials. We will measure this axis both warm and cold for the Q2a-b. It was generally agreed that this method of directly transferring the cold axis to the external fiducial was a good idea that would eliminate a lot of the systematic errors associated with transferring fiducials from cold mass to cryostat.

But there are several questions and comments that need to be addressed. Among them:
-Fermilab must be sure that the test bench is as close as possible to the LHC tunnel, i.e. mechanical supports, vacuum loads.
-We plan to measure the magnetic axis of Q2a, Q2b and correctors separately. This gives us the option of weighting the Q2a Q2b alignment separately. Remnant fields from "off" magnets may be a significant problem. Problem may be eliminated by "AC" measurement techniques.
-Do we really need to measure Q2a-b separately? The answer seems to be "yes" because studies by Tanaji Sen on Q2a and Q2b indicate that we might benefit from weighting the magnetic centers.
-Magnetic lengths are measured absolutely on the 10**-3 level. Relative error will be better... How well do we have to do?
-Since not all KEK magnets will be measured cold-in-cryostat at Fermilab

Will the warm-cold alignment and harmonics corrections be understood well enough after 1-2 magnets?

Relative calibration of DCCT and harmonic probes KEK vs. FNAL takes on larger importance

Mechanical Issues

Talks by Tom Nicol and Fred Nobrega outlined the construction of the cold mass and cryostat construction. The intra-alignment issues for the cold mass are pretty well understood. The use of an alignment key in the skin of the Q2a-b will be of great benefit. Tests are scheduled for early 2000 on the relative alignment of the Q2a-b cold masses.
Other issues:
-Details about how to validate alignment of mechanical components. Interplay of mechanical measurements vs. magnetic measurements
-The reliability of our plan to do at Fermilab cold magnetic axis to cryostat fiducial transfer depends on the mechanical stability issues. Is the axis stable WRT thermal cycles? Transit from FNAL to CERN?
-Related to above, Q2a-Q2b is not a completely rigid body, the location of the spider supports in the cryostat, as well as the cryostat jack stand will have an impact on the final location of the coldmass in the cryostat.
-How are the correctors to be attached to the MQX magnets?

Issues related directly to KEK magnets

-Who will weld on the lugs that will be used for the cryostat spider interface?
-There needs to be a procedure to relate lug locations to precision alignment holes on the KEK coldmass.

CERN and the stretched wires

Related to the issue of mechanical stability of the magnetic axis, we discussed the possibility of measuring all or some of the magnets at CERN. Fermilab is providing CERN with essentially a clone of the Fermilab stretched wire system. This exchange will serve two purposes. The stretched wire system will be used to measure ARC quadrupoles and the results compared to the CERN rotating coil system. This will serve as a means of cross calibrating the two systems. Secondly, the system could re-measure the US cryostated quads to see if the magnetic centers have moved relative to the external fiducials.

On a related note, it was suggested that fiducial marks should be placed on the front face of the cold masses. These fiducials should be visible in the room temperature environment. These cold-mass fiducials could be surveyed prior to installation relative to the cryostat fiducials as a crosscheck